7.9 BEAT FREQUENCY

Activity 7.9.1 Beats from Nearly Identical Tuning Forks

(Pages 264–265)

Two identical mounted tuning forks are situated side by side and an elastic band is fitted over a prong of one of the tuning forks. The two are struck and the resulting sound is observed. A second elastic band is added to the same prong and the procedure is repeated. Lastly, the elastic bands are removed and the two tuning forks are struck once again.

(a) When the first elastic band is added to a prong of one of the tuning forks and the two are struck, "beats" are heard. A regularly varying sound intensity is heard with each 'loud – silent" variation considered a "beat". The frequency of the tuning fork with the elastic band has been slowed by the greater mass, giving it a slightly lower pitch. (The frequency of the beats is simply the difference between the frequencies of the two tuning forks. For example, if the frequencies of the two tuning forks are 440 Hz and 438 Hz, a beat frequency of 2 Hz—2 beats per second—will be heard.)

When a second elastic band is added to the tuning fork its frequency will lower even more, resulting in a greater difference in frequencies between the two tuning forks and a greater beat frequency.

When the elastic bands are removed entirely no beats are observed. The two tuning forks have the same frequency.

(b) An oscilloscope tracing of the resulting sound of two tuning forks producing beats will appear as Figure 2 on page 265 of the text—Graph of Resultant Waves. The oscilloscope will vary between this pattern and a straight level line as the sound varies between maximum intensity and minimum intensity with the minimum intensity decreasing to zero (flat line on tracing) during the destructive interference phase of the oscillation.

(c) This activity shows that sound energy travels by means of waves because it clearly demonstrates interference, strictly a wave phenomenon. When the sound energy reaches the observer's ears a silent point will result when the waves from the two sources are exactly out of phase. A maximum intensity is observed when the two are exactly in phase.

PRACTICE

(Page 266)

Understanding Concepts

1. $$\begin{aligned}\text{beat frequency} &= |f_1 - f_2| \\ &= |514\ \text{Hz} - 512\ \text{Hz}| \\ \text{beat frequency} &= 2\ \text{Hz}\end{aligned}$$

2. $$\begin{aligned}\text{beat frequency} &= \frac{\text{number of beats}}{\text{total time}} \\ &= \frac{21\ \text{beats}}{3\ \text{s}} \\ \text{beat frequency} &= 7\ \text{Hz}\end{aligned}$$

$$\begin{aligned}\text{beat frequency} &= |f_1 - f_2| \\ 7\ \text{Hz} &= |200\ \text{Hz} - f_2| \\ f_2 &= 193\ \text{Hz or } 207\ \text{Hz}\end{aligned}$$

Making Connections

3. A note on a guitar is sounded with a tuning fork of corresponding frequency. The guitar string is adjusted until no beats are heard.

Section 7.9 Questions

(Pages 266–267)

Understanding Concepts

1. $$\begin{aligned}\text{beat frequency} &= |f_1 - f_2| \\ &= |302\ \text{Hz} - 300\ \text{Hz}| \\ \text{beat frequency} &= 2\ \text{Hz}\end{aligned}$$

You will hear 2 beats/s.

2. $$\begin{aligned}\text{beat frequency} &= \frac{\text{number of beats}}{\text{total time}} \\ &= \frac{20\ \text{beats}}{4.0\ \text{s}} \\ \text{beat frequency} &= 5\ \text{Hz}\end{aligned}$$

$$\begin{aligned}\text{beat frequency} &= |f_1 - f_2| \\ 5\ \text{Hz} &= |256\ \text{Hz} - f_2| \\ f_2 &= 251\ \text{Hz or } 261\ \text{Hz}\end{aligned}$$

3. (a) beat frequency $= |f_1 - f_2|$

$= |202\text{ Hz} - 200\text{ Hz}|$

beat frequency = 2 Hz

(b) beat frequency $= |341\text{ Hz} - 347\text{ Hz}|$

beat frequency = 6 Hz

(c) beat frequency $= |1003\text{ Hz} - 998\text{ Hz}|$

beat frequency = 5 Hz

4. To help the students develop skill in drawing neat waves, tell them to draw the points outlining the wave first, then draw a very light curve, and finally draw a dark curve representing the wave. Urge them to exercise care when drawing and adding the waves. The resulting pattern, shown in **Figure 1**, shows that when two waves of nearly equal wavelength (and nearly equal frequency) are added or heard together, the waveform produced has periodic constructive and destructive interference, which resembles the production of beats.

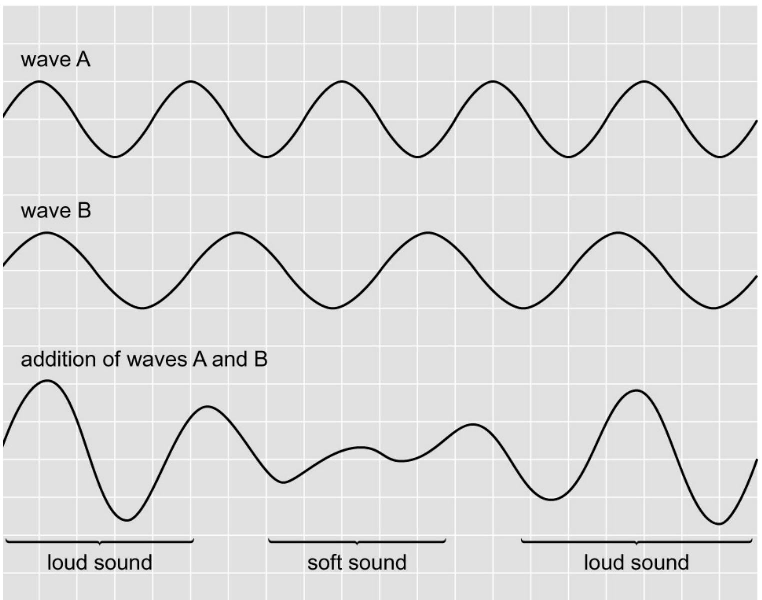

Figure 1

5. beat frequency $= \dfrac{\text{number of beats}}{\text{total time}}$

$= \dfrac{20\text{ beats}}{5.0\text{ s}}$

beat frequency = 4 Hz

beat frequency $= |f_1 - f_2|$

$4\text{ Hz} = |4.0 \times 10^2\text{ Hz} - f_2|$

$f_2 = 404\text{ Hz}$ or 396 Hz

6. beat frequency $= \dfrac{\text{number of beats}}{\text{total time}}$

$= \dfrac{18\text{ beats}}{3.0\text{ s}}$

beat frequency = 6 Hz

beat frequency $= |f_1 - f_2|$

$6\text{ Hz} = |410\text{ Hz} - f_2|$

$f_2 = 404\text{ Hz}$ or 416 Hz

The frequency of the second fork from question 5 is 404 Hz.

7. beat frequency $= |f_1 - f_2|$

$3\text{ Hz} = |440\text{ Hz} - f_2|$

$f_2 = 437\text{ Hz}$ or 443 Hz

When an elastic band is wrapped around one prong of the tuning fork, the frequency of the fork goes down because of the slightly greater mass. If the frequency of the guitar string had been 443 Hz, the new fork frequency would have been either 441 Hz or 445 Hz, both of which are impossible. Thus, the frequency of the guitar string must be 437 HZ; the new fork frequency would be either 439 Hz or 435 Hz, which corresponds to the condition that it must be lower than 440 Hz.

Making Connections

8. Using a pitch pipe to tune a piano. If a note on a piano is sounded with a tuning fork or pitch pipe of corresponding frequency, beats are heard. The tension of the piano wire can be adjusted until no beats are heard.